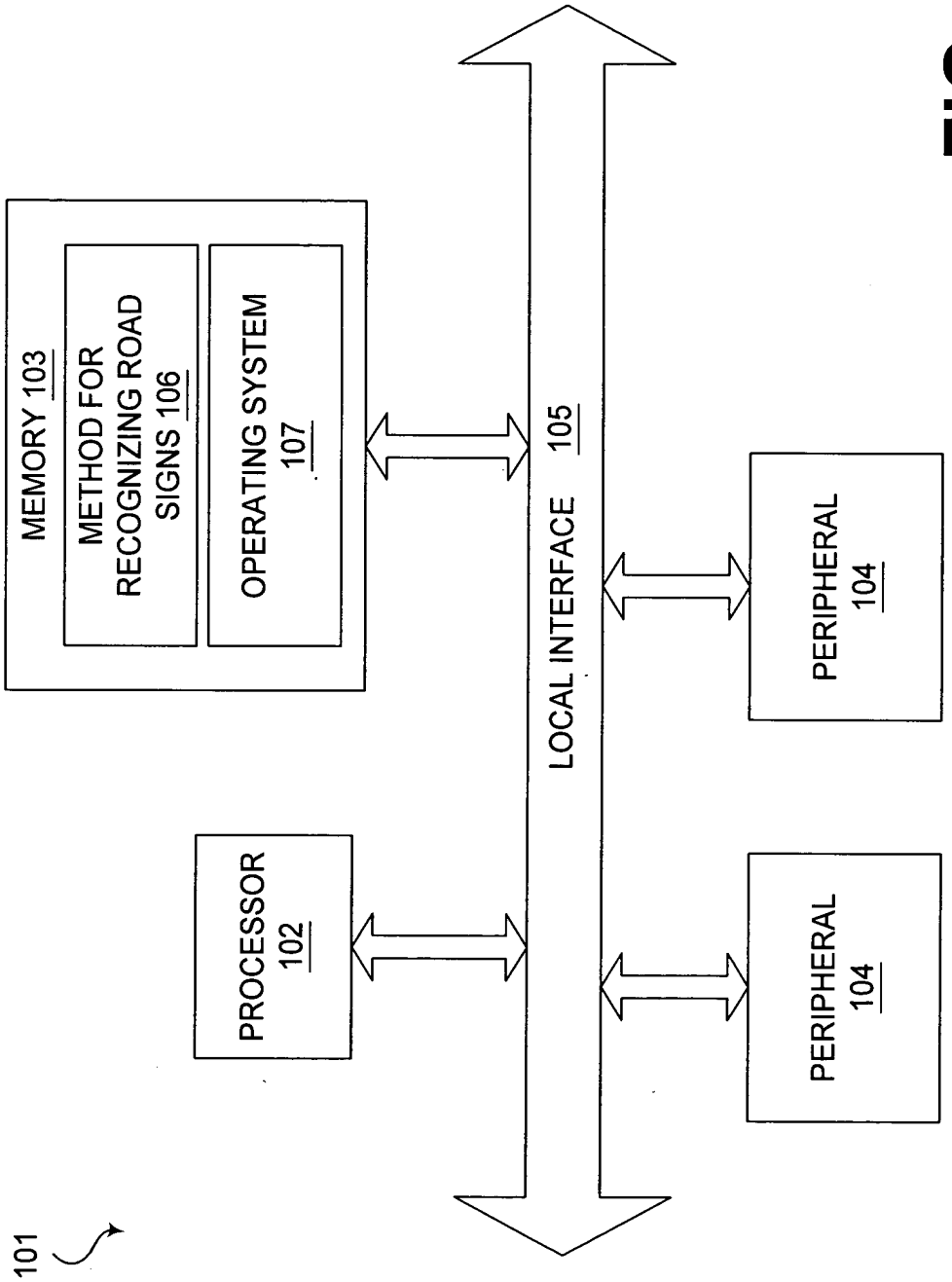

101
MEMORY 103
METHOD FOR RECOGNIZING ROAD SIGNS 106
OPERATING SYSTEM 107
PROCESSOR 102
LOCAL INTERFACE 105
PERIPHERAL 104
PERIPHERAL 104

FIG. 1

FIG. 2

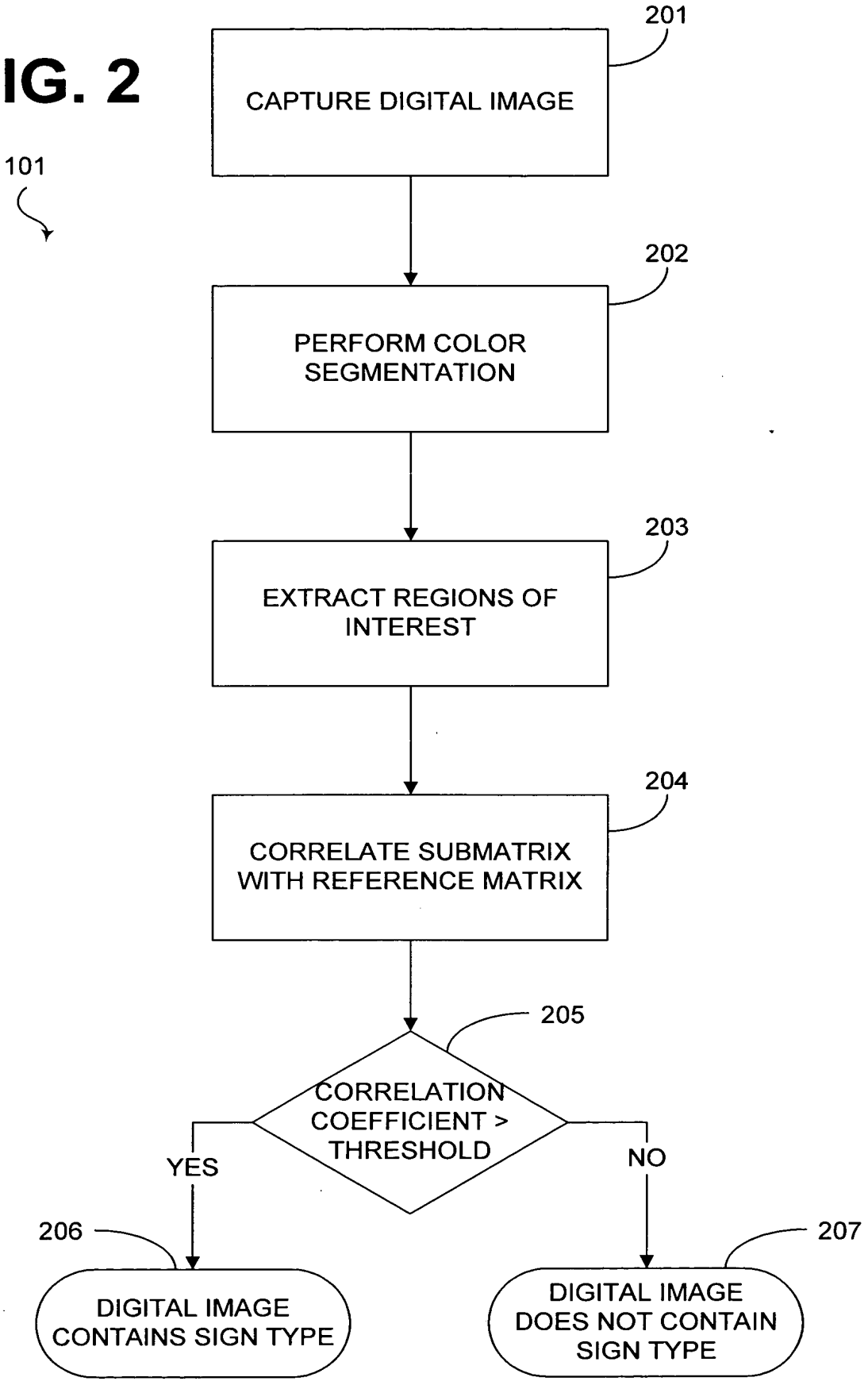

101
201
CAPTURE DIGITAL IMAGE
202
PERFORM COLOR SEGMENTATION
203
EXTRACT REGIONS OF INTEREST
204
CORRELATE SUBMATRIX WITH REFERENCE MATRIX
205
CORRELATION COEFFICIENT > THRESHOLD
YES
NO
206
DIGITAL IMAGE CONTAINS SIGN TYPE
207
DIGITAL IMAGE DOES NOT CONTAIN SIGN TYPE

FIG. 3

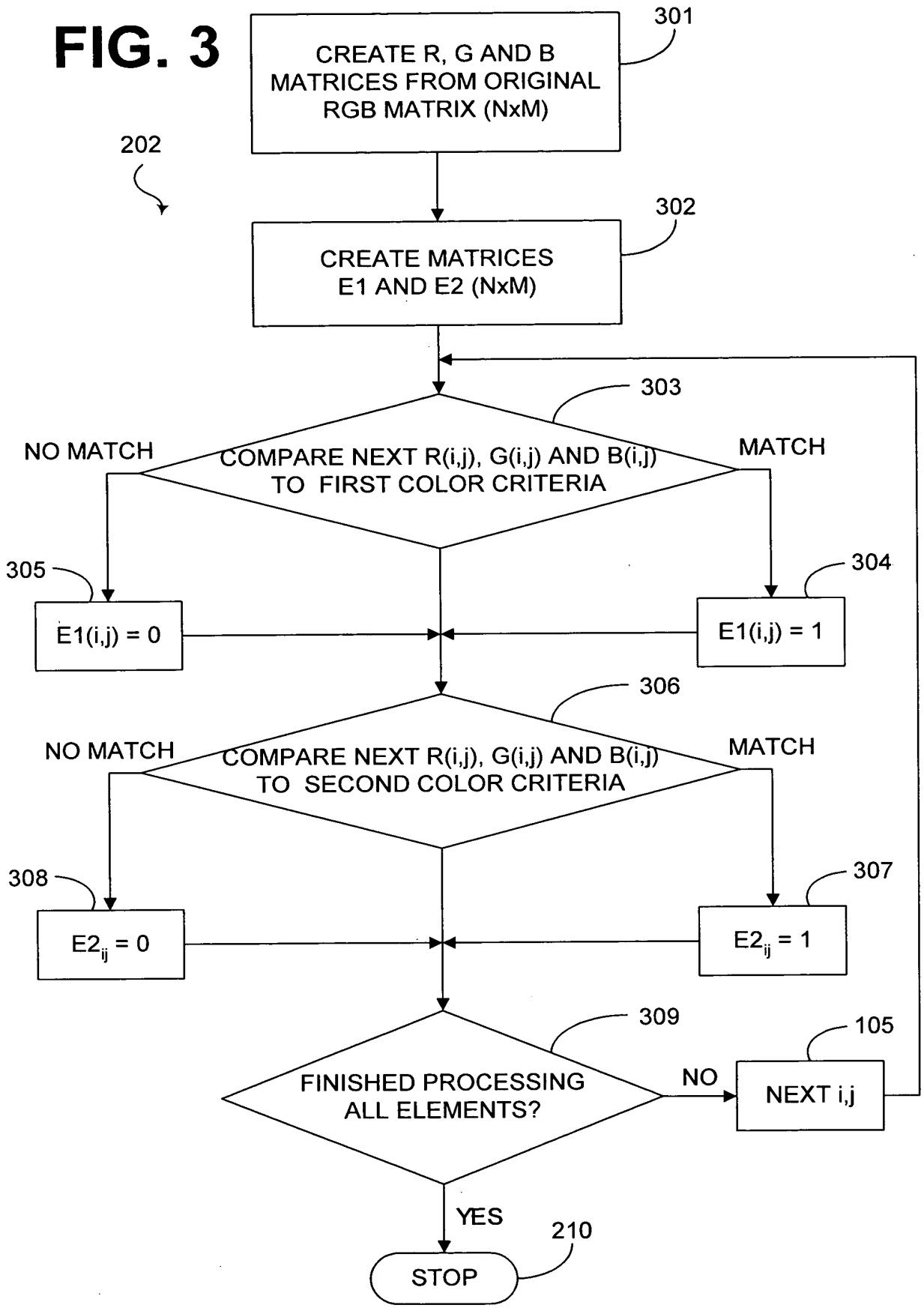

301
CREATE R, G AND B MATRICES FROM ORIGINAL RGB MATRIX (NxM)
202
302
CREATE MATRICES E1 AND E2 (NxM)
303
COMPARE NEXT R(i,j), G(i,j) AND B(i,j) TO FIRST COLOR CRITERIA
NO MATCH
MATCH
305
E1(i,j) = 0
304
E1(i,j) = 1
306
COMPARE NEXT R(i,j), G(i,j) AND B(i,j) TO SECOND COLOR CRITERIA
NO MATCH
MATCH
308
E2ij = 0
307
E2ij = 1
309
FINISHED PROCESSING ALL ELEMENTS?
NO
105
NEXT i,j
YES
210
STOP

FIG. 4

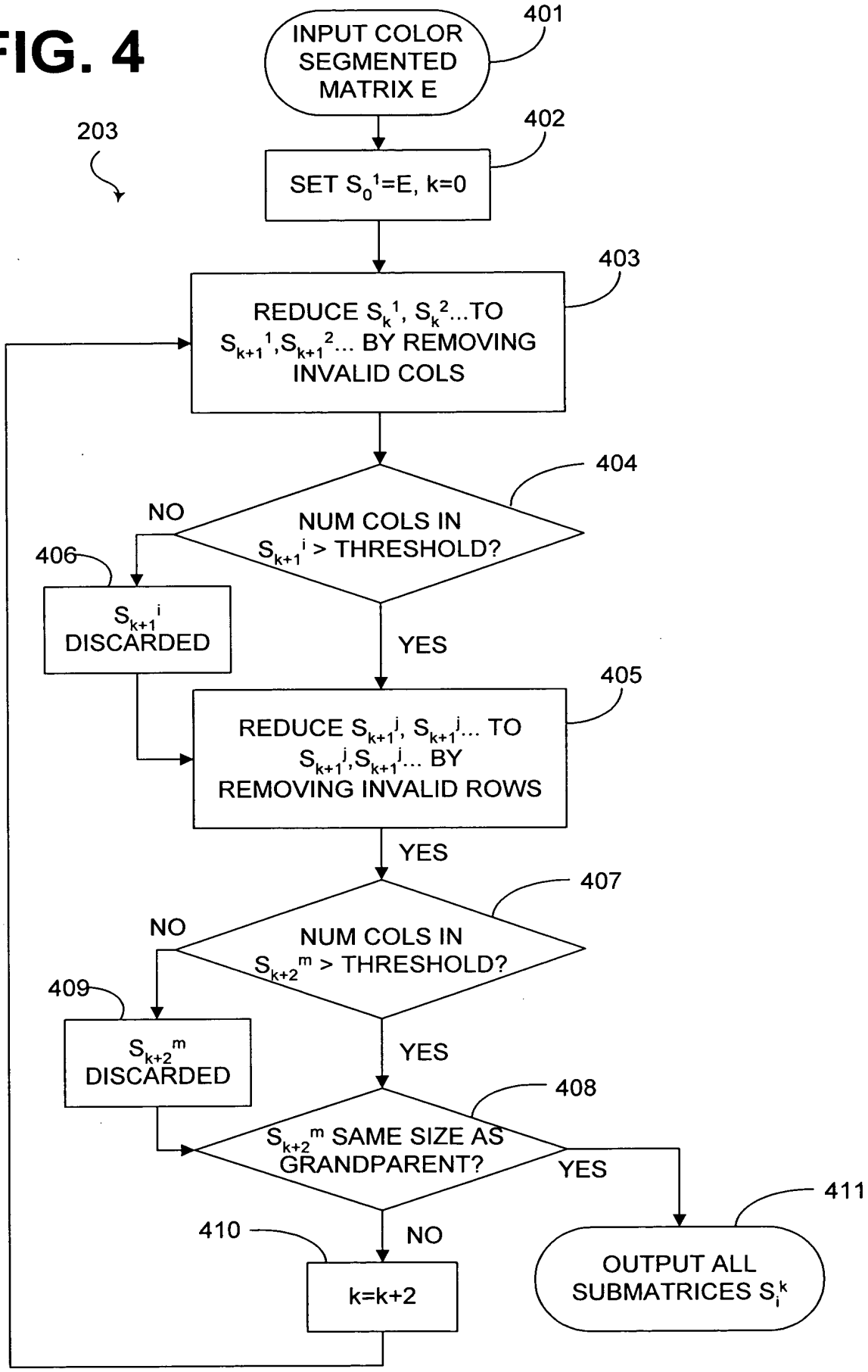

203
401
INPUT COLOR SEGMENTED MATRIX E
402
SET S_0^1=E, k=0
403
REDUCE S_k^1, S_k^2...TO S_{k+1}^1,S_{k+1}^2... BY REMOVING INVALID COLS
404
NUM COLS IN S_{k+1}^i > THRESHOLD?
NO
406
S_{k+1}^i DISCARDED
YES
405
REDUCE S_{k+1}^j, S_{k+1}^j... TO S_{k+1}^j,S_{k+1}^j... BY REMOVING INVALID ROWS
YES
407
NUM COLS IN S_{k+2}^m > THRESHOLD?
NO
409
S_{k+2}^m DISCARDED
YES
408
S_{k+2}^m SAME SIZE AS GRANDPARENT?
YES
411
OUTPUT ALL SUBMATRICES S_i^k
NO
410
k=k+2

FIG. 5A

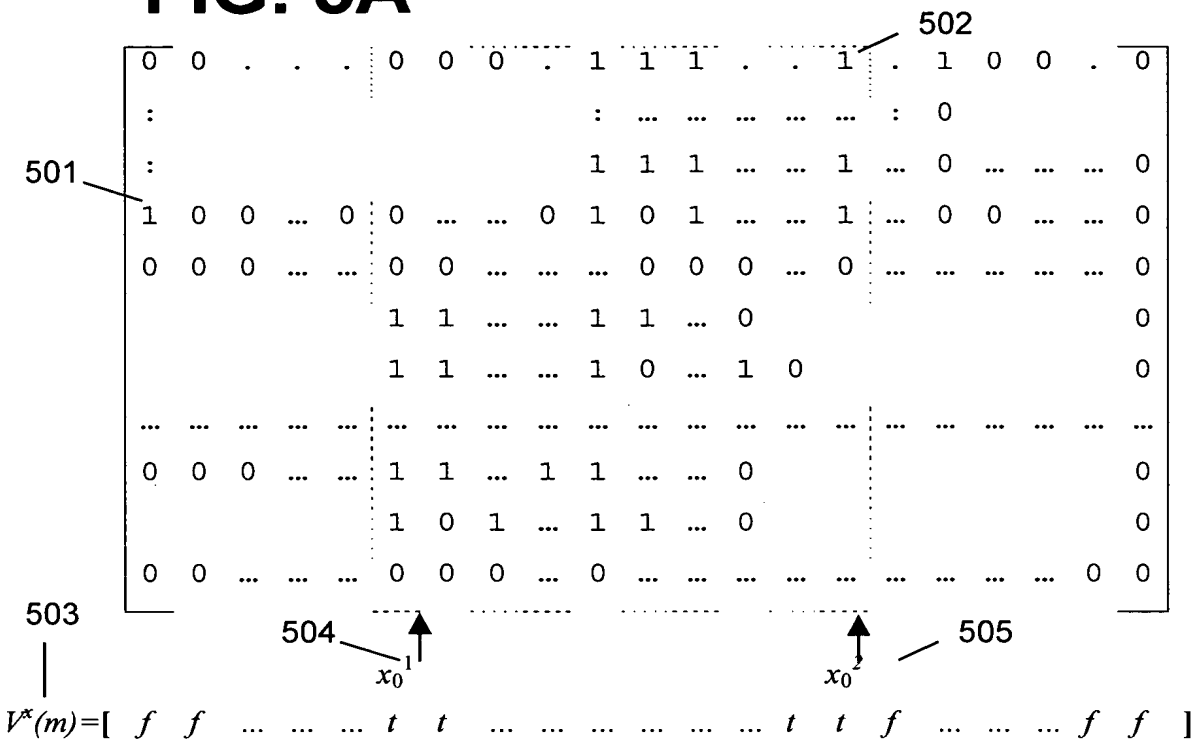

502
501
503
504
505
x_0^1
x_0^2
$V^x(m)$=[f f ... ... t t ... ... t t f ... ... f f]

FIG. 5B

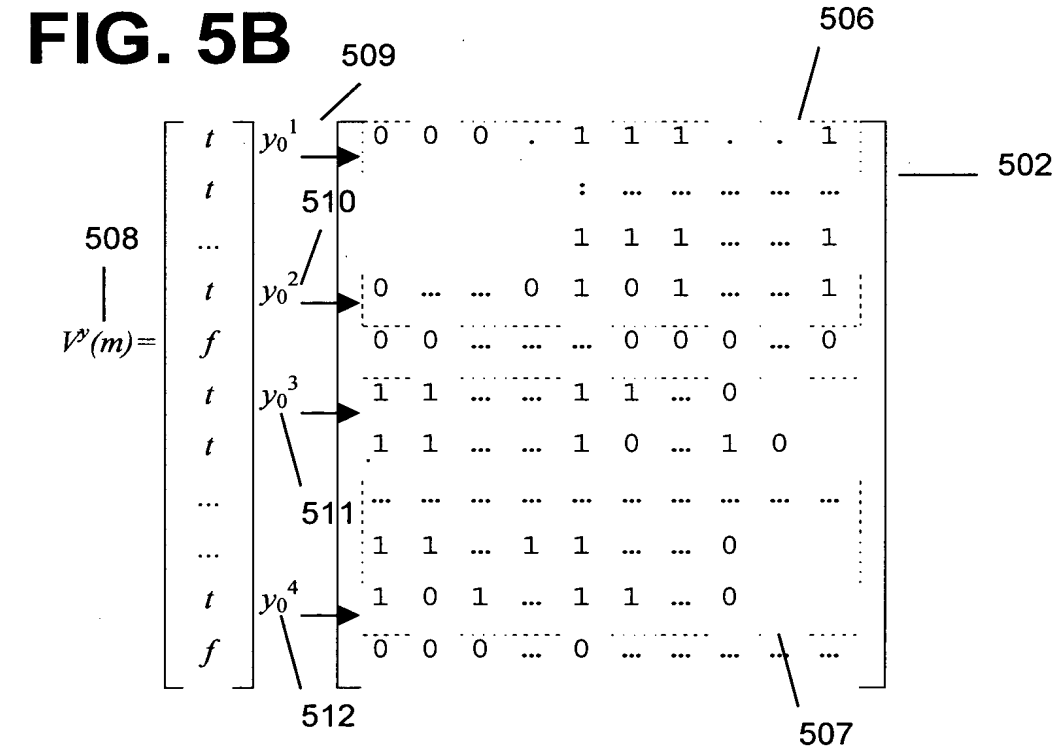

506
509
502
508
510
511
512
507
$V^y(m)$=
y_0^1
y_0^2
y_0^3
y_0^4

FIG. 5C

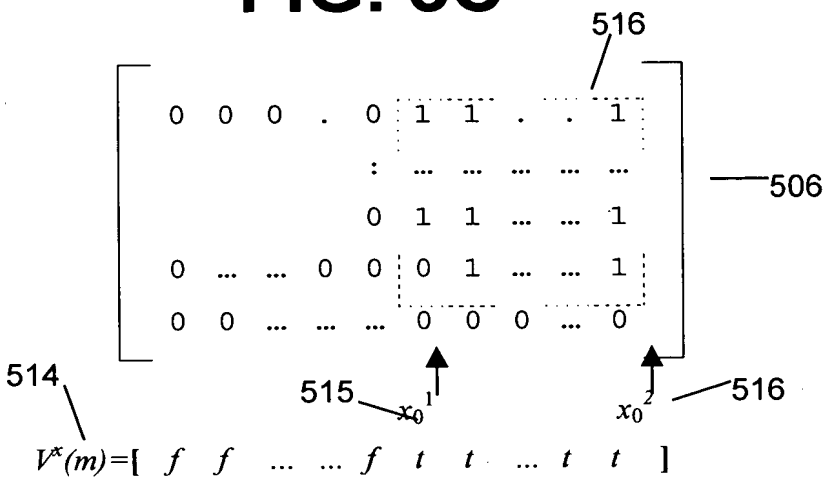

516
0 0 0 . 0 1 1 . . 1
: ... ...
0 1 1 1
0 ... ... 0 0 0 1 1
0 0 ... ... 0 0 0 ... 0
506
514
515
x_0^1
x_0^2
516
$V^x(m)$=[f f ... ... f t t ... t t]

FIG. 6

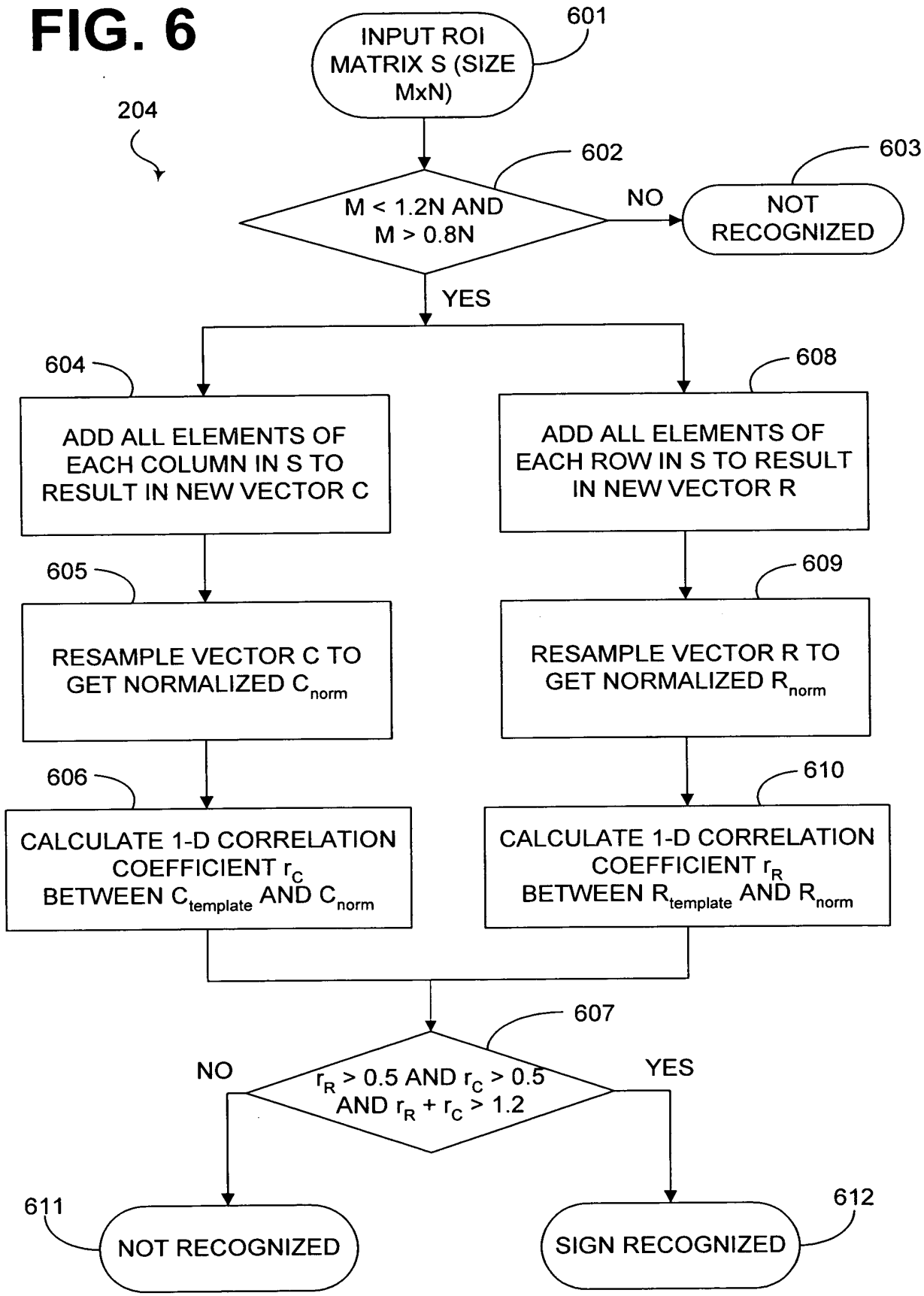

204
INPUT ROI MATRIX S (SIZE MxN)
601
M < 1.2N AND M > 0.8N
602
NO
NOT RECOGNIZED
603
YES
604
ADD ALL ELEMENTS OF EACH COLUMN IN S TO RESULT IN NEW VECTOR C
608
ADD ALL ELEMENTS OF EACH ROW IN S TO RESULT IN NEW VECTOR R
605
RESAMPLE VECTOR C TO GET NORMALIZED C_{norm}
609
RESAMPLE VECTOR R TO GET NORMALIZED R_{norm}
606
CALCULATE 1-D CORRELATION COEFFICIENT r_C BETWEEN $C_{template}$ AND C_{norm}
610
CALCULATE 1-D CORRELATION COEFFICIENT r_R BETWEEN $R_{template}$ AND R_{norm}
607
NO
$r_R > 0.5$ AND $r_C > 0.5$ AND $r_R + r_C > 1.2$
YES
611
NOT RECOGNIZED
612
SIGN RECOGNIZED

FIG. 7

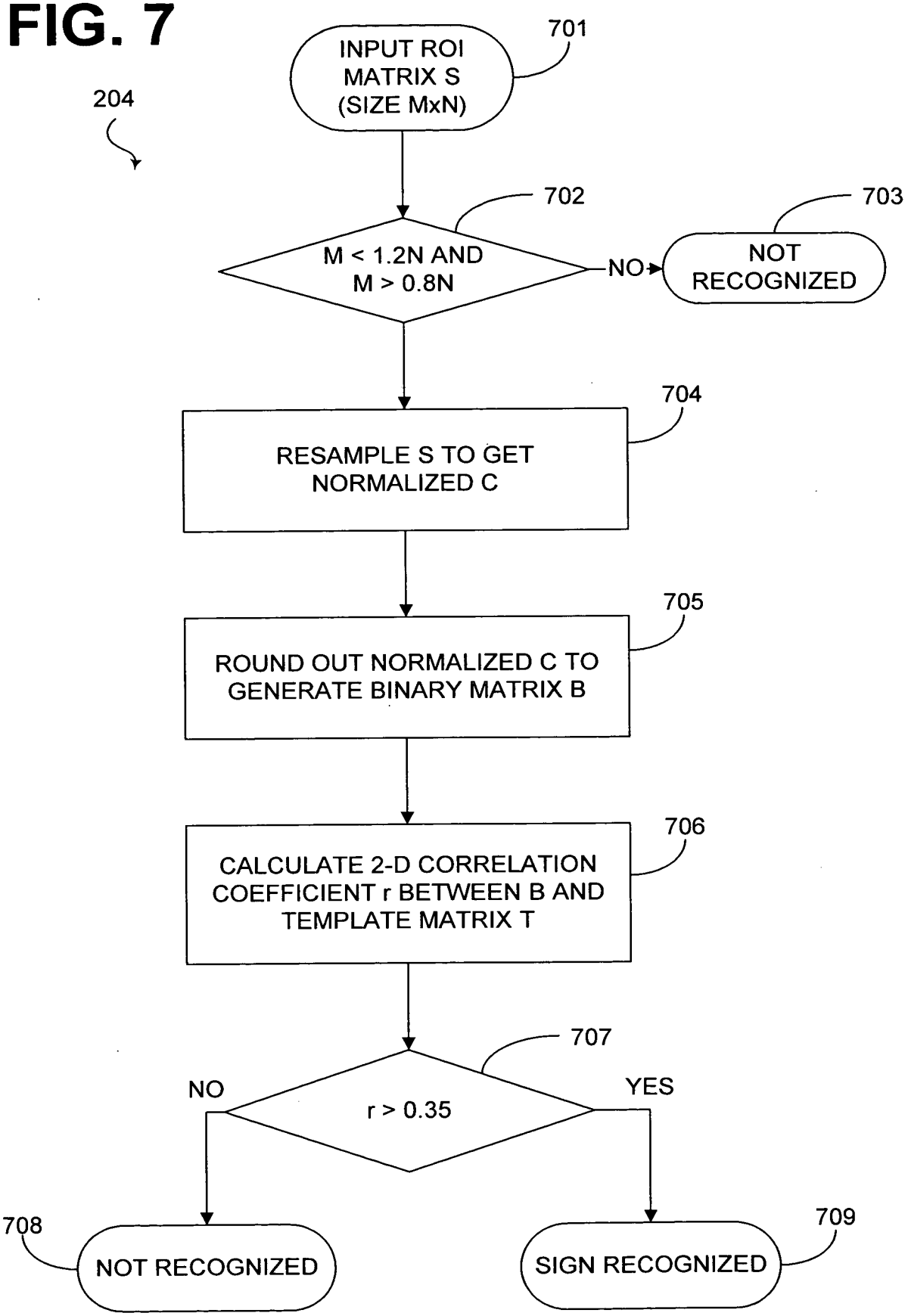

204
INPUT ROI MATRIX S (SIZE MxN)
701
M < 1.2N AND M > 0.8N
702
NO
NOT RECOGNIZED
703
RESAMPLE S TO GET NORMALIZED C
704
ROUND OUT NORMALIZED C TO GENERATE BINARY MATRIX B
705
CALCULATE 2-D CORRELATION COEFFICIENT r BETWEEN B AND TEMPLATE MATRIX T
706
r > 0.35
707
NO
YES
NOT RECOGNIZED
708
SIGN RECOGNIZED
709

FIG. 8

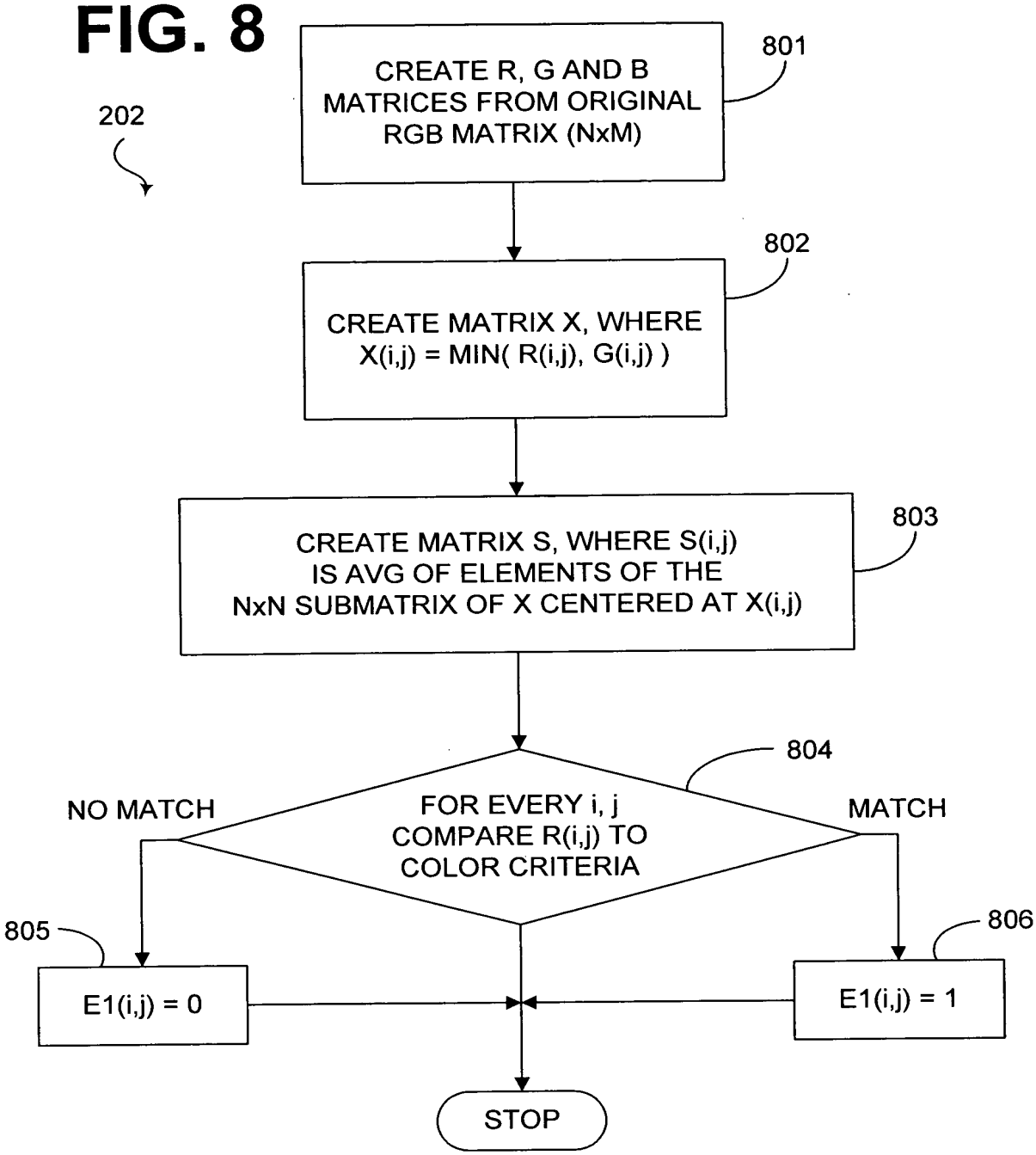

202
CREATE R, G AND B MATRICES FROM ORIGINAL RGB MATRIX (NxM)
801
CREATE MATRIX X, WHERE X(i,j) = MIN(R(i,j), G(i,j))
802
CREATE MATRIX S, WHERE S(i,j) IS AVG OF ELEMENTS OF THE NxN SUBMATRIX OF X CENTERED AT X(i,j)
803
FOR EVERY i, j COMPARE R(i,j) TO COLOR CRITERIA
804
NO MATCH
MATCH
805
E1(i,j) = 0
806
E1(i,j) = 1
STOP

FIG. 9

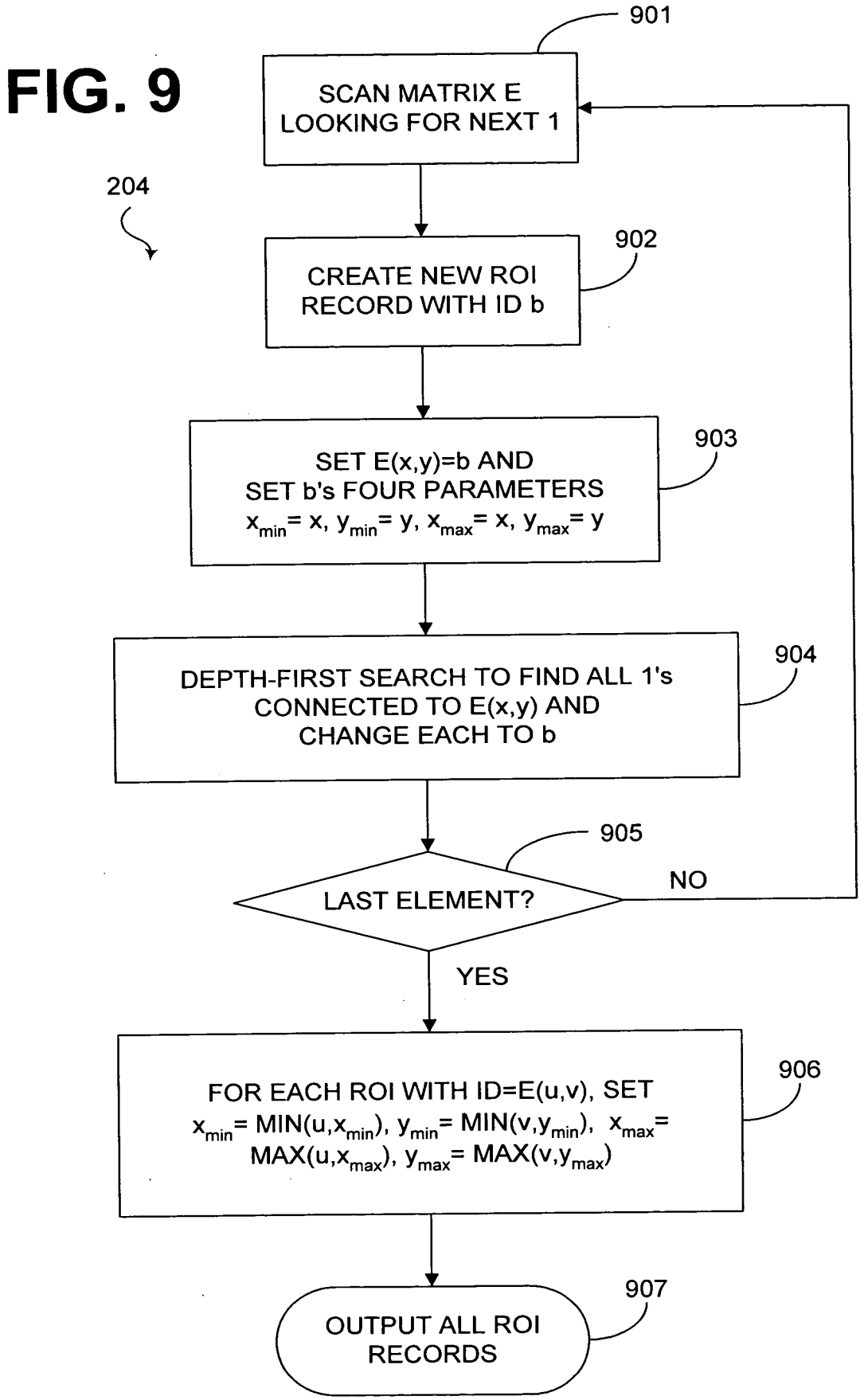

901
SCAN MATRIX E LOOKING FOR NEXT 1
204
902
CREATE NEW ROI RECORD WITH ID b
903
SET E(x,y)=b AND SET b's FOUR PARAMETERS x_{min}= x, y_{min}= y, x_{max}= x, y_{max}= y
904
DEPTH-FIRST SEARCH TO FIND ALL 1's CONNECTED TO E(x,y) AND CHANGE EACH TO b
905
LAST ELEMENT?
NO
YES
906
FOR EACH ROI WITH ID=E(u,v), SET x_{min}= MIN(u,x_{min}), y_{min}= MIN(v,y_{min}), x_{max}= MAX(u,x_{max}), y_{max}= MAX(v,y_{max})
907
OUTPUT ALL ROI RECORDS

FIG. 10A

0	0	0	0	0	0	0	1	1	0
0	0	0	0	0	1	1	1	0	1
0	0	0	0	0	1	1	1	1	1
0	0	1	1	0	1	0	1	1	0
0	0	1	1	0	1	1	1	0	0
0	1	1	1	0	0	1	0	0	0
1	1	1	1	0	0	0	0	0	0
0	0	1	1	1	1	1	1	0	0
0	1	1	1	1	0	1	1	0	0
0	0	0	0	0	0	0	0	0	0

1001

FIG. 10B

~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~*a*~~	1	0
0	0	0	0	0	1	1	1	0	1
0	0	0	0	0	1	1	1	1	1
0	0	1	1	0	1	0	1	1	0
0	0	1	1	0	1	1	1	0	0
0	1	1	1	0	0	1	0	0	0
1	1	1	1	0	0	0	0	0	0
0	0	1	1	1	1	1	1	0	0
0	1	1	1	1	0	1	1	0	0
0	0	0	0	0	0	0	0	0	0

1002 1003 1004 1001

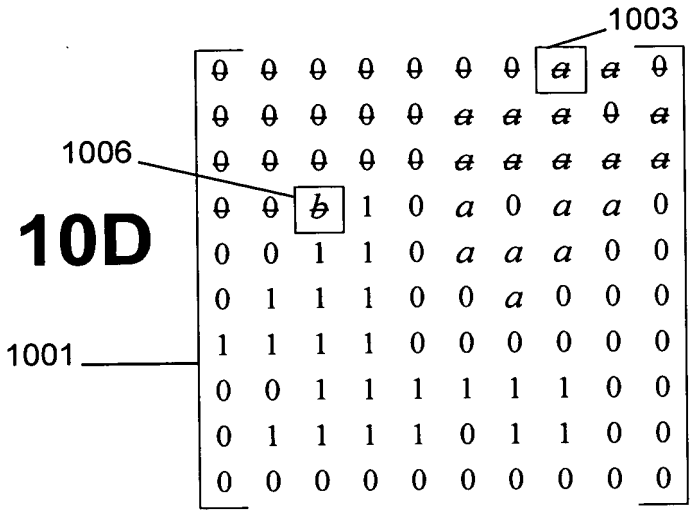
ROI	*a*
x_{min}=	1
y_{min}=	8
x_{max}=	1
y_{max}=	8

FIG. 10C

~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~*a*~~	*a*	0
0	0	0	0	0	*a*	*a*	*a*	0	*a*
0	0	0	0	0	*a*	*a*	*a*	*a*	*a*
0	0	1	1	0	*a*	0	*a*	*a*	0
0	0	1	1	0	*a*	*a*	*a*	0	0
0	1	1	1	0	0	*a*	0	0	0
1	1	1	1	0	0	0	0	0	0
0	0	1	1	1	1	1	1	0	0
0	1	1	1	1	0	1	1	0	0
0	0	0	0	0	0	0	0	0	0

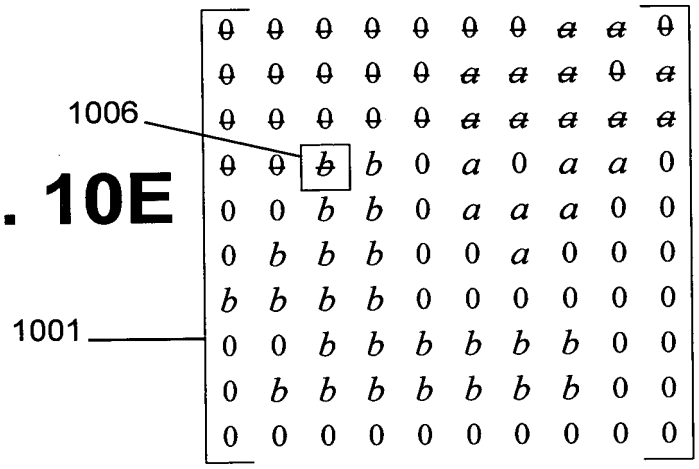
1003 1004 1001

ROI	*a*
x_{min}=	1
y_{min}=	8
x_{max}=	1
y_{max}=	8



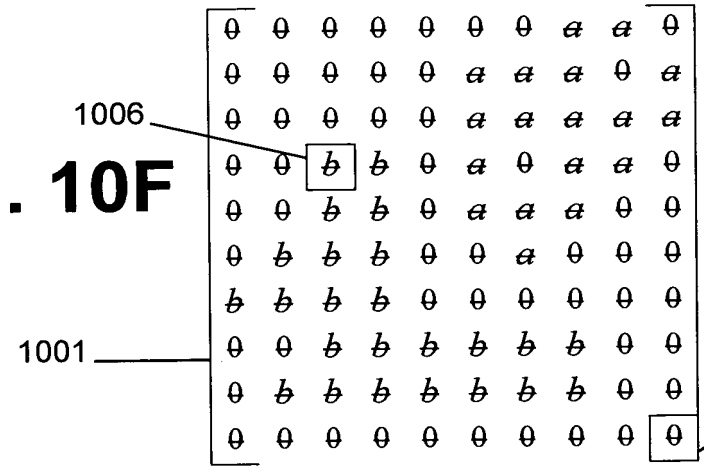
ROI	b
x_{min}=	4
y_{min}=	3
x_{max}=	4
y_{max}=	3

FIG. 10D



ROI	b
x_{min}=	4
y_{min}=	3
x_{max}=	4
y_{max}=	3

FIG. 10E



ROI	b
x_{min}=	4
y_{min}=	3
x_{max}=	4
y_{max}=	3

FIG. 10F

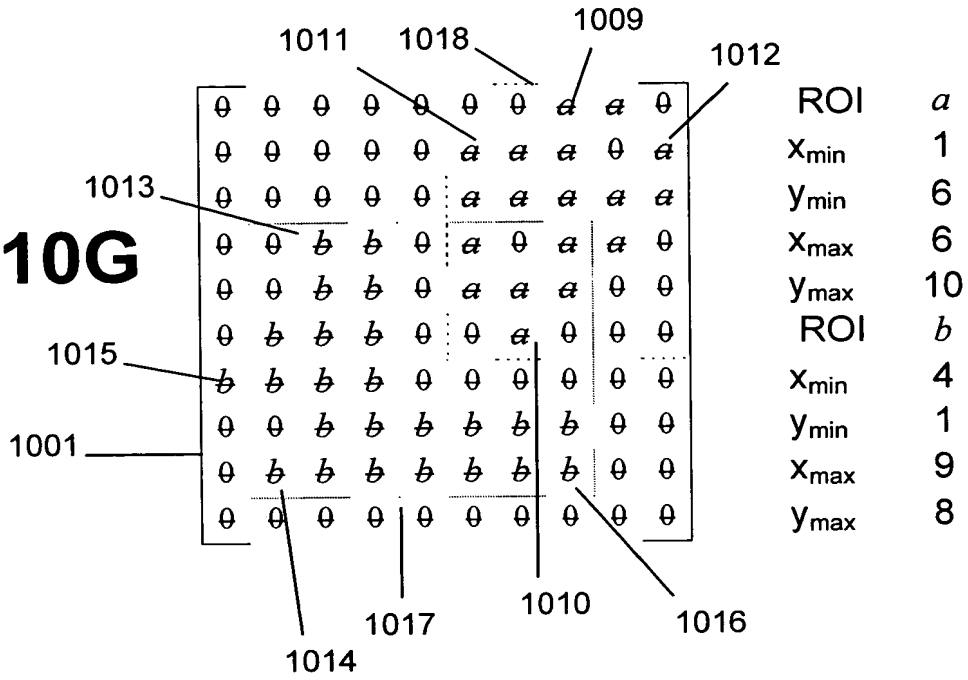
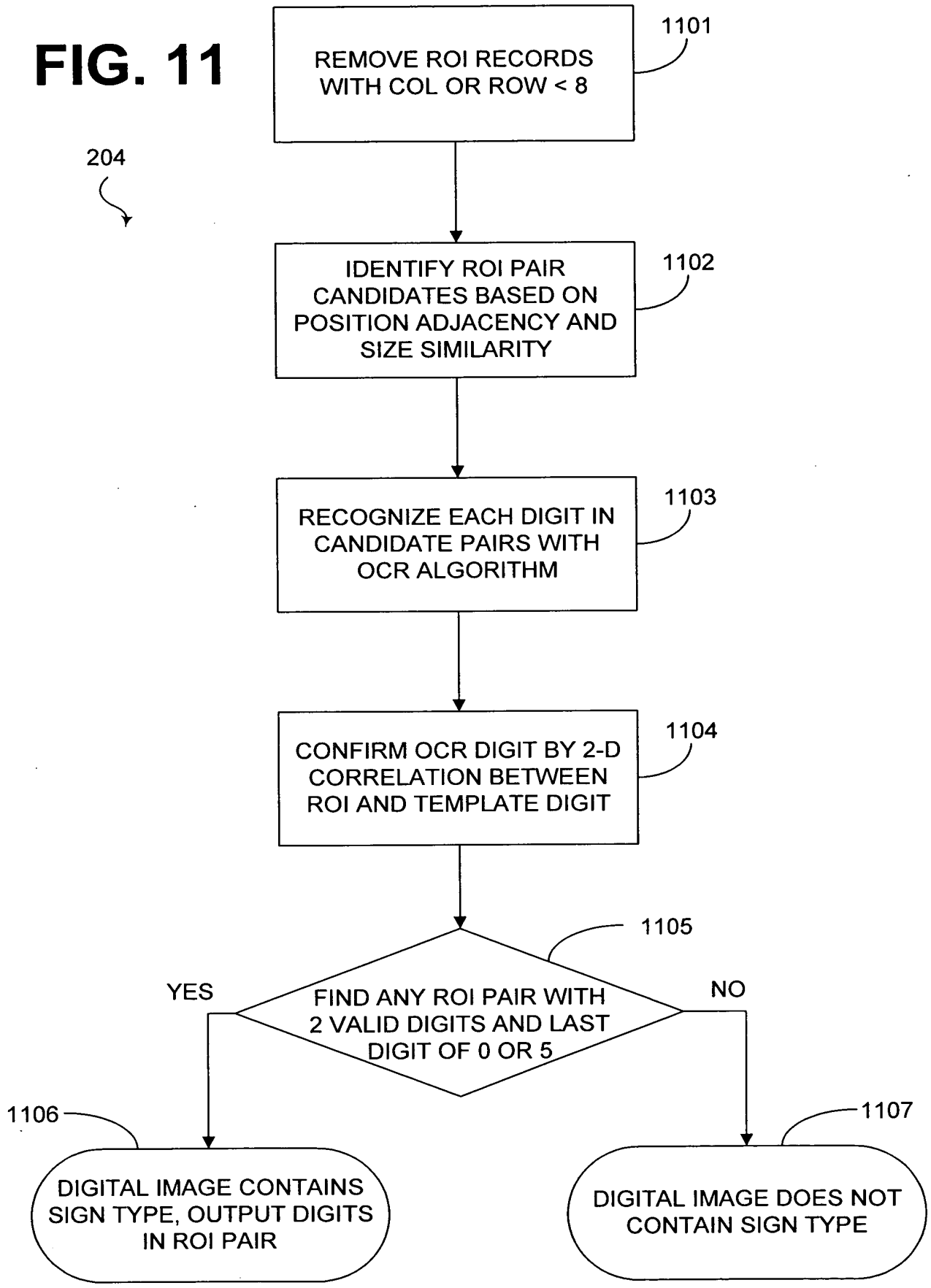

1011
1018
1009
1012
1013
1015
1001
1014
1017
1010
1016
ROI a
x_{min} 1
y_{min} 6
x_{max} 6
y_{max} 10
ROI b
x_{min} 4
y_{min} 1
x_{max} 9
y_{max} 8

FIG. 10G

FIG. 11


204
REMOVE ROI RECORDS WITH COL OR ROW < 8
1101
IDENTIFY ROI PAIR CANDIDATES BASED ON POSITION ADJACENCY AND SIZE SIMILARITY
1102
RECOGNIZE EACH DIGIT IN CANDIDATE PAIRS WITH OCR ALGORITHM
1103
CONFIRM OCR DIGIT BY 2-D CORRELATION BETWEEN ROI AND TEMPLATE DIGIT
1104
FIND ANY ROI PAIR WITH 2 VALID DIGITS AND LAST DIGIT OF 0 OR 5
1105
YES
NO
1106
DIGITAL IMAGE CONTAINS SIGN TYPE, OUTPUT DIGITS IN ROI PAIR
1107
DIGITAL IMAGE DOES NOT CONTAIN SIGN TYPE